Radon Measurement Guide for Schools

A Guide for Iowa Schools: Version 2.0

IDPH
Iowa Department of Public Health

AMERICAN LUNG ASSOCIATION® OF THE UPPER MIDWEST

The purpose of this document is to provide Iowa schools with a protocol for accurately measuring radon levels in school buildings.

Notice

ACKNOWLEDGMENT

The Radon Measurement Guide for Schools was prepared in accordance with Iowa Administrative Code 641 Chapter 43 – Minimum Requirements for Radon Testing and Analysis regulated by the Iowa Department of Public Health.

Any comments regarding this document can be sent to the Iowa Department of Public Health, Lucas State Office Building, 321 E. 12th Street, Des Moines, IA. Phone: (515) 281-7689. Website: http://idph.iowa.gov/radon

Table of Contents

Radon Measurement Guide for Schools

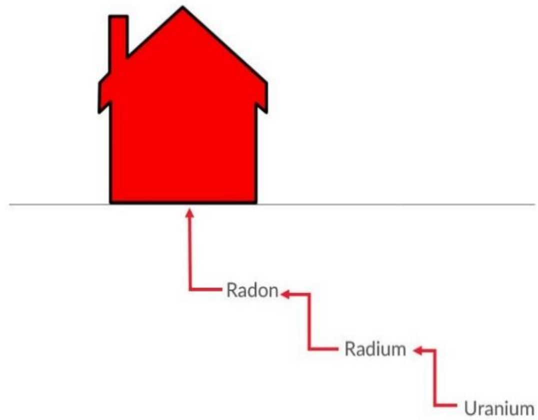
A Guide for Iowa Schools

Guide Objectives

This guide addresses learning objectives for radon screening measurements in schools.

1. To define the elements and components of radon and radon measurement using appropriate labels, terms, and wording, as well as possessing the ability to communicate effectively such definitions to others.
2. To understand the relevant laws and elements of physical science to the radon measurement process, as well as understanding the role of physical science in both the introduction and presence of radon in the environment.
3. To forecast radon occurrences, as well as predicting radon's behavior at different times, in different places, and/or under different circumstances.
4. To measure relevant properties of radon, utilizing appropriate scales of measurement, interpreting both status and progression (change), and the ability to interpret such measurements validly and reliably.
5. To utilize the standard devices and/or instrumentation approved for radon measurement, their calibration and servicing, as well as the potential for errors associated with the misuse or misplacement of such devices.
6. To model the required elements of quality control and quality assurance throughout the measurement process as a continuous part of the measurement protocol and the inherent values of a quality controlled approach to measurement.
7. To comply with existing laws, regulations, and other established procedural requirements associated with radon measurement and emulate the importance of legal oversight of radon-related activities.
8. To understand the processes associated with basic measurement and mitigation so that Iowa schools can manage the potential challenges that come with radon.

Basics of Radon



Radon is a colorless, odorless, tasteless, and radioactive gas that comes from natural deposits of uranium in the soil. Small amounts of uranium are found in the soil throughout the world resulting in every building having the potential for unsafe levels of radon. Radon is present both outdoors and indoors. However, radon is a greater concern within buildings due to higher concentrations typically found in lower levels that have some contact with the soil. Once the gas enters through cracks and openings in the foundation, it is then dispersed throughout the structure. Over time, the radon gas decays to solid radioactive particles that can attach to dust and other fine particles in the air. As these radioactive particles are breathed in, they release small bursts of radiation within the lungs that can harm lung tissue. This radiation can result in damage to the body's DNA, which may lead to the development of lung cancer.

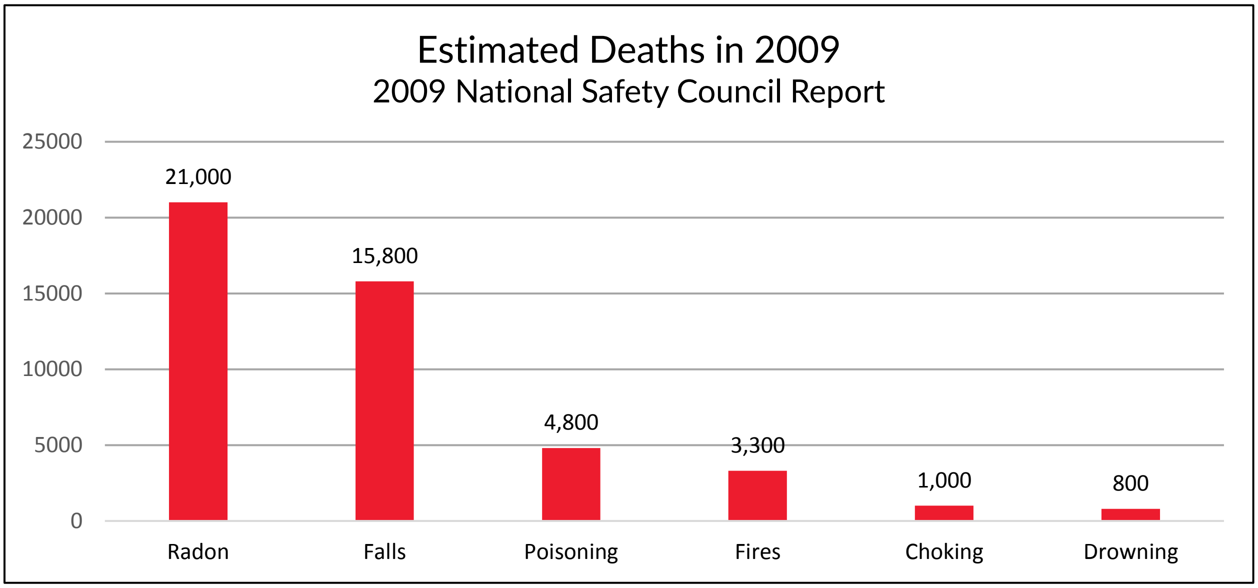
Health Effects of Radon

The United States Environmental Protection Agency (USEPA) ranks radon in the highest classification of cancer causing substances – Group A (known human carcinogens). This category only includes substances that show sufficient evidence to cause cancer in humans. Scientists have estimated the risk of radon through various studies of cancers in humans, such as the underground miner study and more recent epidemiological studies (National Cancer Institute). The U.S. Surgeon General warned Americans about the health risk from the exposure to radon in indoor air and urged Americans to perform radon testing. Released in 2005, the statement acknowledged that radon is the leading cause of lung cancer for non-smokers in the U.S. and breathing radon over prolonged periods can present a significant health risk.

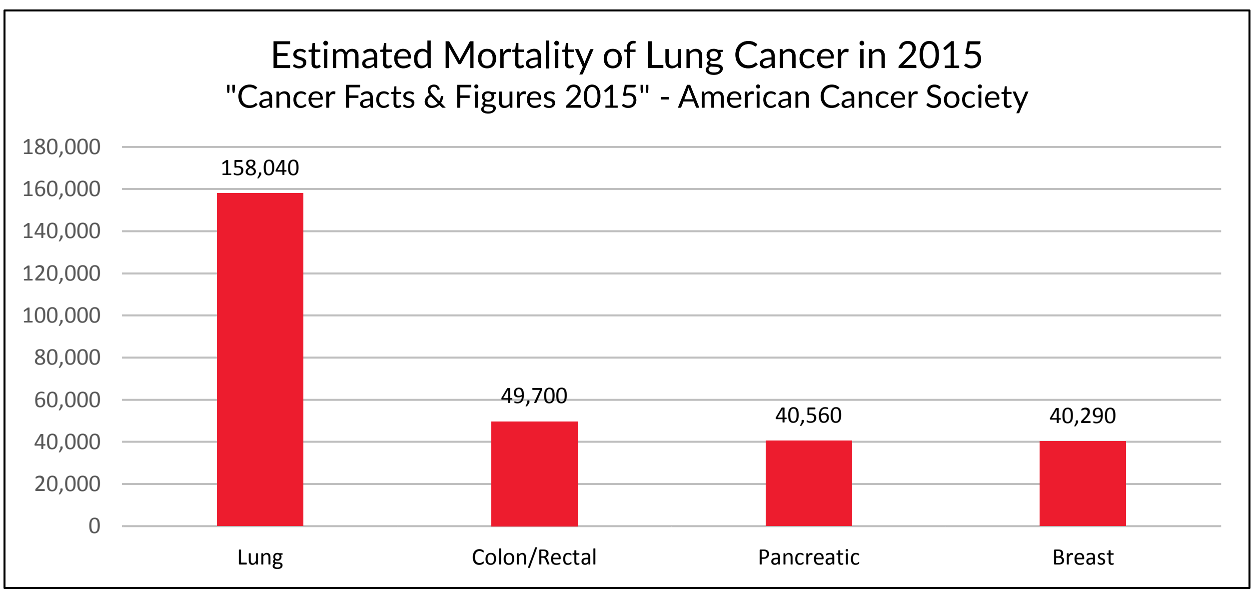
EPA's Classification of Cancer Causing Agents:

- Group A: Known human carcinogen – **RADON**
- Group B: Probably carcinogenic
- Group C: Possibly carcinogenic
- Group D: Not classifiable (no data)
- Group E: Evidence of non-carcinogenicity

The USEPA estimates that 21,000 lung cancer radon-related deaths occur annually in the U.S. with 400 of those in Iowa. The bar chart below is from the 2009 National Safety Council Report.



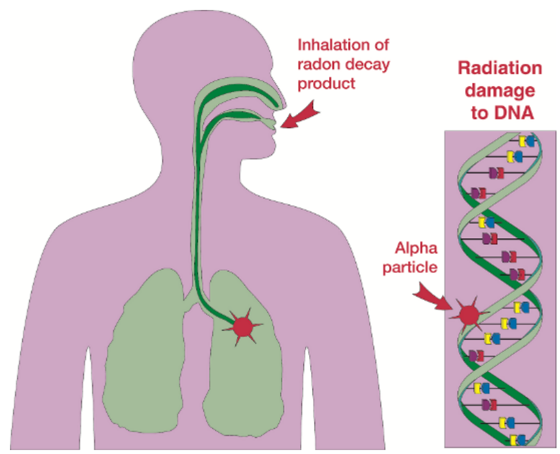
The figure below shows a higher incidence of lung cancer than colon/rectal, breast or prostate cancer. Unfortunately, the survival rate for lung cancer is extremely low when compared to other cancer types. According to the USEPA, only 11 to 15% of those diagnosed with lung cancer will live beyond 5 years.



Not everyone exposed to radon or radon decay products will develop lung cancer. An individual's risk of lung cancer depends on the concentration of radon, the duration of exposure and genetic/health disposition. The risk of dying from lung cancer caused by radon is much greater for smokers than non-smokers.

Children (who have higher respiration rates than adults) have been reported to have greater risk than adults for certain types of cancer from radiation, but there is no conclusive data at this time on whether children are at greater risk than adults if exposed to radon.

Radon and Cancer



Unlike radon, which is a gas, radon decay products are solid particles. These particles either remain suspended in the air or "plate out" by attaching themselves to aerosols, dust, and smoke particles in the air. Inhaling radon decay products (particles) can deliver a radiation dose to the lungs that can damage tissue and DNA.

DNA is the fundamental blueprint for all of the body's structures. The DNA blueprint is encoded in each cell as a long sequence of small molecules linked together into a chain. If unwound, the DNA in a single human cell would be more than 2 meters long. Each cell is continually reading various parts of its own DNA as it constructs new molecules to perform a variety of tasks. Cancer is produced when the DNA code is altered in a way that leaves an error in the DNA blueprint.

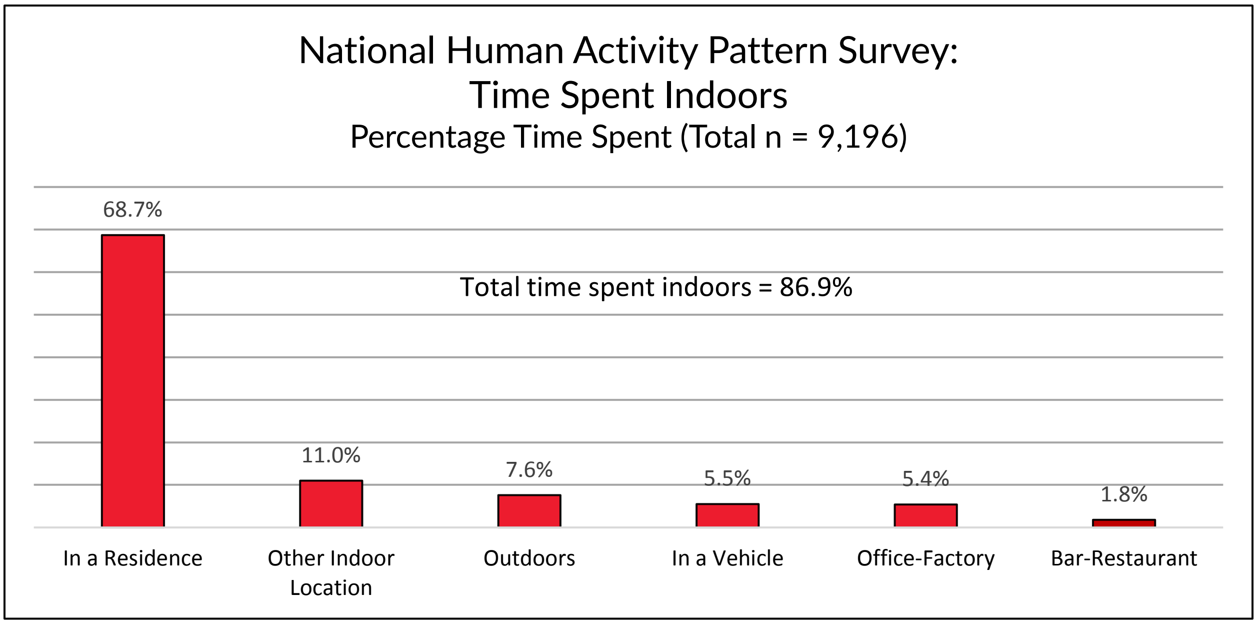
The small radon decay products exert energy (called ionizing radiation) capable of damaging lung tissue and disrupting the cell's DNA. The strike to the DNA can impair the cancer suppressant gene and increase the risk of developing cancer. The collision and ionization happen very quickly, but it may take the biological effects much longer to become apparent. The overall risk of lung cancer is dependent on the exposure concentration and length. The minimal latency period for radon induced lung cancer is approximately 5 years.

Where We Spend Our Time

According to the National Human Activity Pattern Survey, we spend 86.9% of our time indoors on a daily basis (Klepis et al. 2001). The home is likely to be the most significant source of radon exposure since people, particularly children, spend the majority of their time at home. Iowa leads the nation in the percentage of homes over the USEPA Action

Level of 4.0 pCi/L, as well as the percentage of homes over 20 pCi/L. Furthermore, the Iowa Department of Public Health states that surveys in Iowa have found that 7 in 10 homes contain radon concentrations above the USEPA Action Level (Radon Resources).

For most school children and staff, the second largest contributor to their radon exposure is likely to be their school. As a result, both USEPA and the Iowa Department of Public Health (IDPH) recommend that school buildings be tested for radon.



Units of Radon Measurement

In the U.S., radioactive materials are measured in curies. A curie is the amount of radioactivity released from one gram of a radioactive material; a picocurie is a millionth of a millionth or a trillionth of a curie and is measured as 2.22 atomic disintegrations per minute (0.37 disintegrations per second). This unit of radioactivity is used in conjunction with the measurement of 1 liter volume of air. Therefore, the unit of measurement for radon concentration is expressed as picocurie per liter or pCi/L.

USEPA Action Level

USEPA recommends reducing the concentration of radon in indoor environments to below the Radon Action Level of 4.0 pCi/L. This action level is based on the ability of current mitigation technologies to reduce elevated radon levels below 4.0 pCi/L. Depending on the building characteristics, reducing radon levels below the Action Level may (or may not) be possible. *It must be noted that any level of radon carries some risk and no concentration of radon is ever safe.*

Radon Studies on Schools

In 1988, USEPA began investigating radon in schools and found elevated levels of radon in schools in every state. A further study, called the *National School Radon Survey*, showed that 19.3% of all U.S. schools (nearly one in five) have at least one frequently occupied room with short-term radon levels above the USEPA Action Level. In total, USEPA estimates that over 70,000 schoolrooms are impacted by radon (1993).

Routes of Radon Entry

Many factors contribute to the entry of radon gas into a school building. Schools that are in the same community can have significantly different radon levels from one another. As a result, school officials cannot know if elevated levels of radon are present without testing.

Radon Levels in Buildings

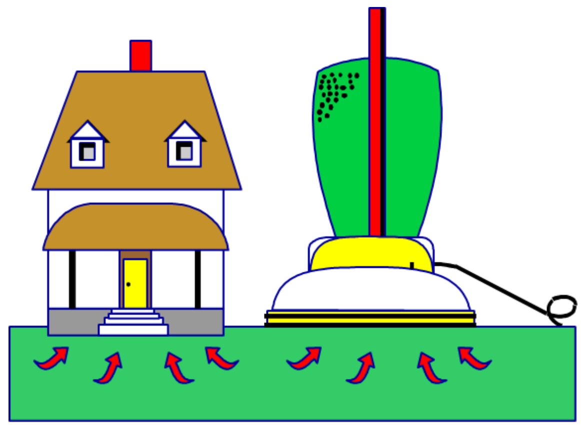
The level of radon in a building depends on:

- The concentration of uranium and radium in the soil or underlying geology.
- How easily the radon can be transported into the building through soil permeability, pathways, and openings into the building.
- The structure and construction of the building.
- The type, design, operation, and maintenance of the heating, ventilating, and air-conditioning system.

Entry Through Pressure-Driven Transport

The most common way for radon to enter a building is through pressure-driven transport. This mechanism is often caused by a natural process of pressure differences between the inside and outside of buildings, and it can develop in a variety of forms. This driving force by which radon gas enters buildings can be the result of induced soil suction, temperature-induced pressure differentials, and thermal bypasses. While each method is slightly different, they all depend on differences in air pressure to draw the radon gas from the soil.

Induced soil suction is caused by buildings acting as a vacuum that draws in the radon gas. While these vacuums, also known as air pressure differentials, are typically small, they can greatly affect the concentration of radon in buildings.



Similar to induced soil suction, temperature-induced pressure differentials are directly related to the differences in temperature between the inside and outside air. When air temperature inside the building is warmer than the outside air, a stack effect develops. The stack effect causes warm inside air to rise, escape, and be replaced by cooler, denser air in the lower portions of the building. This process results in soil and radon gas being drawn into the structure.

The stack effect can be enhanced in the presence of small openings in the structure like cracks in the floor, recessed lighting, plumbing chases, and air gaps around a chimney. Known as thermal bypass, this process allows for upward movement of air causing increased levels of radon within the structure.

Other environmental factors, such as storm systems, can have a big impact on the rate of radon entry into buildings. With these systems, the region typically experiences lower air pressure as well as higher winds. Both of these factors can lead to an enhanced rate of radon entry. Similarly, local ground freezing and thawing affects the permeability of the soil leading to an easier pathway for radon to travel.

Entry Through Diffusion

Radon also enters buildings when there are no pressure differences. This type of radon movement is called diffusion driven transport. Diffusion is the same mechanism that causes a drop of food coloring placed in a glass of water to spread through the entire glass. Diffusion driven transport is rarely the cause of elevated radon levels in existing buildings. It is also highly unlikely that diffusion contributes significantly to elevated radon levels in schools and other large buildings.

Entry Through Building Materials

Radon emanating from building materials is possible, but has rarely been found to be the cause of elevated levels in existing schools and other large buildings. Typically building materials, such as concrete, block, brick stones for fireplaces, granite and sheet rock contain some radium and are sources of indoor radon. The extent of the use of radium-contaminated building materials is unknown but is generally believed to be very minor.

Entry Through HVAC Systems

Depending on design and operation, HVAC systems influence radon levels in schools by increasing ventilation (diluting indoor radon concentrations with outdoor air); decreasing ventilation (allowing radon gas to build up); pressurizing a building (keeping radon out); or depressurizing a building (drawing radon inside).

Proper HVAC maintenance plays an important role in providing an adequate amount of fresh air and ventilation in school buildings. For example, if air intake filters are not periodically cleaned and changed, this can significantly reduce the amount of outdoor air ventilating the indoor environment. Less ventilation allows radon to build-up indoors. An understanding of the design, operation, and maintenance of a school's HVAC system and its influence on indoor air conditions is essential for understanding and managing a radon problem, as well as many other indoor air quality concerns in schools.

Entry Through Other Mechanisms

Other building features, such as a basement area, crawl spaces, utility tunnels, sub slab HVAC ducts, cracks, or other penetrations in the slab (e.g., around pipes) also provide areas for radon to enter indoor spaces.

Environmental Factors Influencing Radon Concentrations

Radon levels vary constantly – daily and seasonally. In the summer, with windows and doors open and warmer temperatures, radon concentrations are expected to be lower. During these warm months when buildings are either open or well ventilated through air conditioning, the indoor radon levels are largely determined by geologic rather than mechanical factors. In contrast to summer, radon levels are typically highest in the winter time. This is often caused by heating systems pulling air up and out of the home causing an enhanced stack effect.

Lowest Level

Highest Level

Radon concentrations can also fluctuate from many other environmental factors:

- Frost – "Caps" the soil so negative pressure of the building is exerted on a larger area.
- Rain – Often accompanied with barometric pressure changes, rain can also "cap" soil and force soil gas into building.
- Wind – Causes positive soil pressure transporting radon into buildings.
- Open Windows – Reduces vacuum thereby reducing radon entry into building.

Types of Radon Measurement Devices

There are two types of radon test kits:

1. Passive – Does not require external power to operate.
2. Active (continuous) – Requires external power to operate

For school district testing, it is recommended to use a passive device. Passive devices are "opened" or "uncapped" and exposed to concentrations through passive airflow for a length of time known as the measurement period.

Alternatively, active devices require an electrical power source and are capable of charting radon gas concentration fluctuations throughout the course of a given measurement period (usually by producing integrated periodic measurements over a period of two or more days).

Passive Radon Measurement Devices

Examples of passive devices include:

- Activated Charcoal Adsorption Devices (AC)
- Electret-Ion Chambers (EIC)
- Alpha Track Detectors (AT)

Activated Charcoal Adsorption Devices (AC)

The charcoal within AC devices have been treated to increase its ability to continuously adsorb and desorb radon. During the entire measurement period (typically two to seven days), the adsorbed radon undergoes radioactive decay. Once the testing period is completed, ACs must be promptly returned to the laboratory using the mail service that guarantees delivery to the laboratory within two to three days at maximum. The lab is able to determine the radon concentration by counting the decay from the radon absorbed to the charcoal on a gamma detector. A calculation is then used based on calibration information to obtain the radon levels that the building experienced during the testing period.

Various types of ACs are commercially available. A device commonly used contains charcoal packaged inside an air-permeable bag. Another device is a circular container that is filled with activated charcoal. One side of the container is fitted with a screen that keeps the charcoal in but allows air to diffuse in the charcoal. For some of these devices, the charcoal container has a diffusion barrier over the opening to improve the uniformity of response to variations of radon concentration over time.

Advantages of AC Devices:

- Inexpensive
- Do not require power to operate
- Can be sent through the mail
- Can be deployed by anyone
- Accurate

Disadvantages of AC Devices:

- Should be analyzed by laboratory as soon as possible after removal from building
- Highly sensitive to humidity
- No way to detect tampering
- Results biased towards last 24 hours of deployment

Electret Ion Chambers (EIC)

Electret Ion Chambers take advantage of the electrical charge of airborne particles emitted from the decay of radon and radon decay products. Once a plunger at the top of the device is opened, radon gas can enter the main chamber of the device through a filter. The radon gas inside the chamber then decays and creates charged particles, which become attracted to an electrostatically charged disc in the EIC chamber. This disc reacts to their presence by losing some of its charge. The electret is then removed from the chamber and its voltage is measured with a specialized reader both before and after the measurement period. The difference between these two voltage readings is used to calculate the average radon concentration.

Electrets are available for both short term and long term use; these are commonly called ES (short-term) & EL (long-term). ES may be deployed for 2-7 days while EL may be deployed for 1-12 months. The type of electret and chamber volume determine the usable measurement period.

Advantages of EIC Devices:

- Results can be given immediately
- Does not require power
- Can be reused after reading the voltages

Disadvantages of EIC Devices:

- Sensitive to background radiation
- Sensitive to altitude
- Voltage measurements should be done at the same temperature
- Difficult to detect tampering

Alpha Track Detectors (AT)

Alpha Track Detectors consist of a small piece of plastic or film encased in a container with a filter covered opening. Radon diffuses into the container and its alpha particles/radon decay products strike the detector producing submicroscopic damage to the plastic. At the end of the measurement period, the detectors are returned to a laboratory. The damaged tracks are counted using a microscopic or counting mechanism. The counted number of tracks are mathematically correlated to the radon concentration in air. AT devices are most commonly deployed for long-term testing at 3 to 12 months.

Advantages of AT Devices:

- Inexpensive
- Does not require power to operate
- Can be sent through the mail
- Can be deployed by anyone
- Accurate

Disadvantages of AT Devices:

- Can only be used for long-term testing – cannot be used for real estate testing where quick results are needed
- No way to detect tampering

Active Radon Measurement Devices

Active devices include the continuous radon monitor requiring a power source. These devices are expensive to use in a school because one device would be needed for each room. The device collects air samples either mechanically or passively and utilizes a detection monitor to read radon concentrations. Operation is complex due to calibration and other concerns. These devices are generally used by licensed measurement professionals. However, it may be useful during follow-up measurements if rooms have elevated radon concentrations.

Short Term vs. Long Term Radon Tests

There are two ways to use radon test kits for radon testing:

1. Short Term - A short-term test is the quickest way to test for radon. The testing device remains in an area (e.g., classroom) for a period of 2 to 90 days depending on the device. A short-term test is less likely to give an average radon level for a school year, because radon levels tend to vary from day to day and from season to season.

   Activated Charcoal devices may be used to conduct school screening measurements. These devices are simple to operate, place and can be used without any assistance. Test kits may be purchased in a hardware store, department store, home improvement store, or ordered through the mail or internet. Electret Ion Chamber devices, are also simple to operate and place, but may be more costly to purchase and operate.

2. Long Term - A long-term test remains in place for more than 90 days. A long-term test (e.g., a test conducted over the school year) will give a result that is more likely to represent the school year average radon level in a classroom. However, long term devices are typically more expensive to purchase and operate.

Radon Measurement Protocol

The short-term test is the suggested method. To ensure adequate school test results, use only radon measurement devices that can be deployed for a minimum of 48 continuous hours.

For school districts, a short-term test using the three-step approach below is recommended.

Step 1: Test Preparations

It is imperative to have a complete understanding of the building characteristics as well as the typical operating conditions before testing for radon. Pre-test documentation needs to include a detailed floor plan of the school building, identification of the unique sectors of the structure, and an accurate understanding of the normal occupancy of various sectors within the school. Floor plans should make note of all ground contact rooms along with the specific foundation type such as slab-on-grade, basement, or crawl space. These test preparations are vital in the quality control and assurance of the radon testing. It allows schools to maintain a well-documented account of the testing procedure to ensure that follow-up or future testing methods are completed in an appropriate fashion.

Within the floor plan documentation, it is necessary to classify the unique sectors within the school. A unique sector is defined as a section of the building where either individual heating/cooling units or central HVAC systems provide service to ground contact rooms. The heating and cooling design group of each unique sector should be documented with a short description or noted in the floor plan diagram. See Appendix A, Table 1 for more details about HVAC design grouping.

The operational characteristics of the HVAC system, along with the overall design of the system, are critical pieces of information to gather before radon testing can proceed. HVAC setback is an energy-saving strategy that reduces the amount of supplied heating, cooling, or ventilation to certain rooms between occupied and unoccupied periods. Typically, schools maintain HVAC setback schedules that detail the exact hours of operation. Setback schedules are important for radon specialists in order to determine that HVAC systems are in normal use during testing periods.

Finally, there needs to be an accurate identification of typical occupancy use within the school. The pre-test documentation or diagram should include details on the occupancy use in each unique sector of the building. Details that need to be included are:

- Number of months per year that the building or unique sector is significantly occupied.
- The hours of the day where each unique sector is significantly occupied.
- Other areas where occupants may reside for more than 4 hours per day.

- Areas that are not currently occupied but may be in the future.

The goal of this documentation is to determine a time period that represents normal occupied operating conditions for each unique sector. Details on this time frame should be written out in a manner that is similar to Table 2 in Appendix A. Also, it is highly recommended that schools have all their HVAC systems inspected before moving forward with the radon test to ensure each system is operating correctly.

Step 2: Initial Measurements

Initial measurements should be short-term measurements of at least 48 hours to 90 days depending on the device used and should be conducted in all frequently occupied rooms in contact with the soil (slab-on-grade, a basement, berm, a room above a crawlspace or any combination). Upper floors need to be tested as well.

- A surveillance of the building should be done prior to placement of devices.
- Frequently occupied rooms include classrooms, offices, conference rooms, gymnasiums, auditoriums, cafeterias and break rooms. All rooms should be tested simultaneously.
- A minimum of one test kit must be placed every 2,000 square feet of open floor area.
- All teachers or frequent adult occupants should be aware that the room is being tested.
- Schools shall only be tested for radon during periods when the HVAC system is operating as it does normally.
- A decision to mitigate should not rely solely on these initial screening measurements.

Step 3: Follow-Up Measurements

If the results of a radon screening test in any frequently occupied room are found to be 4.0 pCi/L or above, it is recommended that the school district hire a licensed radon professional to perform follow-up measurements before making any mitigation decisions.

All follow-up measurements in a school should be conducted simultaneously. Follow-up measurements should be in the same locations and under the same conditions as the initial measurements (to the extent possible, including similar seasonal conditions and especially HVAC system operation). This will ensure that the two results are as comparable as possible.

The higher the initial short-term test result, the more important it is to use a short-term test as a follow-up, rather than a long-term test. In general, the higher the initial measurement, the greater the urgency to conduct a follow-up test. For example, if the initial short-term measurement for a room is several times the radon action level (e.g., 8.0 pCi/L or higher), a short-term follow-up measurement should be conducted immediately.

Occupied vs. Unoccupied Conditions

There needs to be at least one follow-up measurement completed in each unique sector with a device that can accurately separate occupied and unoccupied conditions. This is to ensure that there has been no mischaracterization of the radon concentration due to the operational characteristics of the HVAC system. These special follow-up tests can be done in combination with other follow-up testing that is completed throughout the school as long as the building and outdoor temperature conditions are consistent with the initial measurement.

A continuous radon monitor (CRM) is the recommended device to perform these follow-up measurements. CRMs are able to integrate, record, and produce viewable measurements in 1 hour time increments, which is beneficial when determining various occupancy conditions. The following items will needed to be reported individually:

- The average radon concentration for the full measurement period
- The average derived from the combined averages of the occupied periods
- The average derived from the combined averages of the unoccupied periods

If the CRM reveals high concentrations of radon during unoccupied periods, schools may elect to investigate if an exposure issue exists. If it is found that no exposure issue based on occupancy exists, the school may change ventilation or adjust HVAC setback schedules among other things.

Adjusting the HVAC settings is another method that can be completed to test for occupied and unoccupied conditions. By making appropriate adjustments to the HVAC system, various occupancy conditions can be simulated in the unique sectors. It should be noted that this method should be done in coordination with the school maintenance staff.

How Are Results Interpreted?

It is not recommended that schools use a single short-term test as the basis for determining mitigation action. Follow-up tests should be completed when initial measurement results are above the Radon Action Level of 4.0 pCi/L. There are multiple follow-up options that schools can choose from depending on the level of initial radon measurements.

Two follow-up testing options exist when initial measurements are between 4.0 pCi/L and 8.0 pCi/L. A short-term follow-up test is often times the easiest and most convenient option for schools that need to retest. For this option, the two measurement results from initial and follow-up tests need to be averaged to determine the need for mitigation. Short-term tests may in some cases reflect an unusual peak in radon concentration, thus indicating a need for remedial action that might not be necessary. By averaging the two measurement results, it reduces the possibility of misrepresenting the overall radon concentration of the testing area.

Schools also have the option of choosing a long-term follow-up test. Long-term tests are completed for periods of at least 91 days to a year. For the long-term option, initial measurements and follow-up measurements should not be averaged since they are completed at different time periods and under different testing conditions. The results of the long-term follow-up alone is enough to determine the need for mitigation.

There is a greater urgency to retest when initial measurements are greater than 8.0 pCi/L. Therefore, it is highly recommended that a short-term follow-up test be used when concentrations are above this level. Short-term tests provide a quicker snapshot of the average radon concentrations in the building, which allows schools to make a mitigation decision sooner when compared to a long-term follow-up test. Should the short-term follow-up test reveal radon concentrations below 4.0 pCi/L, schools should take mitigation action as well as make an investigation into the cause behind the large variance in initial and follow-up results. More information on precision and accuracy of radon measurements are detailed later sections.

When Should Periodic Retesting Be Conducted?

In addition to initial and follow-up measurements, it is recommended that schools retest periodically, or after significant changes to the building structure or the HVAC system have been made, whichever is less.

Suggested times for retesting are as follows:

1. If no mitigation is required after initial testing (e.g., all rooms were found to have levels below 4 pCi/L), retest all frequently occupied rooms in contact with the ground every 5 years. As a building ages and settles, radon entry may increase due to cracks in the foundation or other structural changes.

2. If radon mitigation measures have been implemented in a school, retest these systems as a periodic check on any implemented radon reduction measures.

3. If major renovations to the structure of a school building or major alterations to a school's HVAC system are planned, retest the school before initiating the

renovation. If elevated radon is present, radon-resistant techniques can be included as part of the renovation.

4. Retest after major renovations to the structure of a school building or after major alterations to a school's HVAC system. These renovations and alterations may increase radon levels within a school building.

What Rooms Should Be Tested?

Radon levels in schools often vary greatly from room to room in the same building. A known radon measurement result for a given classroom cannot be used as an indicator of the radon level in adjacent rooms. Therefore, it’s recommended that schools conduct initial measurements in *all frequently occupied rooms in contact with the soil* and indicate each location on the floor plan diagram. Frequently occupied rooms are usually classrooms, offices, laboratories, cafeterias, libraries, and gymnasiums. A minimum of 1 detector every 2000 sq. ft. open floor is required. Schools should only test for radon when the HVAC system is operating as it does normally when the building is occupied, even if the testing occurs when school is not in session or during long holidays.

While radon concentrations are typically higher in the lower levels of buildings, upper floors should be included in the testing procedure. For schools, this means testing in at least one room on each floor. Tests need to be completed in at least 10% of rooms on the second and third level above soil contact areas and in any rooms above an untested ground contact area. Testing on upper floors should also be completed in a manner in which one test is not directly above or below rooms being tested on other floors.

Areas such as rest rooms, hallways, stairwells, elevator shafts, utility closets, and storage closets need not be tested. (Note: these areas may be important areas for diagnostic testing if elevated radon is found).

Recommendations for Specific School Building Design

- Slab-on-Grade Design: Measure only frequently occupied rooms in contact with the ground.
- Open-Plan or Pod Design: If sections of a pod have moveable walls that can physically separate them from other sections, measure each section separately. If moveable walls are absent or inoperable, measure the pod as one room placing test kits every 2,000 square feet.
- Crawl Space Design: If classrooms are above an enclosed crawl space, measure rooms directly above the crawl space.

- Basement Design: In addition to measuring all frequently occupied basement rooms, measure all frequently occupied rooms above the basement that have at least one wall with substantial contact with the ground.

Quality Assurance Measurements

Quality Assurance (QA) measurements should be taken to ensure that the testing results are reliable. Quality assurance refers to maintaining the minimum acceptable standards of precision and accuracy during the entire data collection process. When radon measurement test kits are placed at the school, additional test kits, which serve as quality assurance measurements should also be deployed. If using passive devices, quality assurance requirements include the need to collect duplicate and field blank requirements.

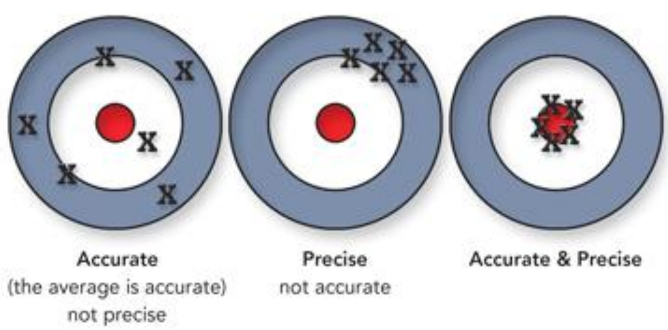
The detector component of the test kit is capable of measuring the radon concentration. Quality assurance measurements include side-by-side test kits (duplicates) and unexposed control test kits (blanks).

What Is Precision and Accuracy?

It is important to have quality control procedures in place to collect reliable data. This data provides the mathematical assurance that is necessary to validate the data.

Precision is measured by calculating the Relative Percent Difference (RPD) between two measurements. The RPD compares two numbers for quality control of repeated measurements when the outcome is expected to be the same and also serves as an indicator of the precision (or validity) of the measurement results. When two numbers are the same, the RPD is zero.

Accuracy is how close the measured value is to the target value. This can be determined by using the Relative Percent Error (RPE) formula. This formula is used when comparing spiked measurements with known concentrations of radon. See infographic below to better understand the difference between precision and accuracy.



Relative Percent Difference (Precision) Formula:

- M1 = result 1
- M2 = result 2
- Find difference: Subtract small number from the larger number
- Find average: (M1 + M2) / (Number of results)
- RPD = (Difference / Average) * 100

Example Use of RPD Formula:

- Two simultaneous long-term devices exposed to the same 97 day period and reported to the lab measurements of 4.1 pCi/L and 4.6 pCi/L. What is the RPD?
- Difference = 4.6 – 4.1 = 0.5 pCi/L
- Average = (4.1 + 4.6) / 2 = 4.4 pCi/L
- RPD = (0.5 / 4.4) * 100 = 11.4%

Relative Percent Error (Accuracy) Formula:

- RPE = (Measured Value – Target Value) / Target Value x 100
- Example: Measured Value = 4.2 pCi/L Target Value = 4.0 pCi/L
- RPE = (4.2 – 4.0) / 4.0 x 100 = 5%

Duplicate Measurements

Duplicates provide an indication of the precision of the measurement.

- Duplicates are pairs of test kits placed in the same location side-by-side for the same measurement period. The number of duplicates should be 10% of all measurements taken in a school building (not to exceed 50 extra test kits). Duplicates are stored, deployed, placed, removed and shipped to the laboratory for analysis in the same manner as the other measurement test kits so that the processing laboratory cannot distinguish between them.
- Because duplicates are placed side-by-side (approximately 4 inches apart), the measured value for these duplicates should be the same. For duplicate pairs, where the average of the two duplicates is greater than or equal to 4.0 pCi/L, the Relative Percent Difference (RPD) between the two measurements should not exceed more than 27%. If they do, each measurement is questionable. Problems in handling the test kits during the measurement process, in the laboratory analysis, or in the test kit itself, may introduce error into the test results.

- Duplicate data provide an indication of precision of measurement (see the above section). If the data is not within the expected level of precision, the cause of the problem should be investigated.
- The table below is a guide to understanding precision error. The percentages shown are based on the Relative Percent Difference between the duplicate measurements.

If results are	Expected Precision	Within Control	Warning	Limit
≥4 pCi/L	0 – 14%	0 – 27%	28 – 36%	>36%
2.0 – 3.9 pCi/L	0 – 25%	0 – 49%	50 – 67%	>67%

- The test kit placement log, mentioned above, should be used to document the devices used. Duplicate devices should be included in the test kit log.

Blank Measurements

Blanks can be used to determine whether the manufacturing, shipping, storage, or processing of the test kit has affected the accuracy of the measurements. They are called blanks because they are not used in the room where a measurement is conducted. Blanks should have results at or near 0.0 pCi/L. Any value other than 0.0 pCi/L is an indication that a problem has occurred with the test kit or laboratory analysis.

- Blanks are unwrapped (but not opened) and immediately rewrapped at the end of the exposure period. They are shipped with the other test kits so the laboratory cannot distinguish between them. The number of blanks should be 5% of all the test kits used (or 25, whichever is less).
- When 50 or more test kits are deployed, testers should increase the number of blanks to nine. Three lab-transit blanks shall be returned to the laboratory immediately in order to evaluate the quality prior to test kit deployment. Three office blanks shall remain in the office location where detectors are stored and handled. They shall then be returned to the lab with the sampling detectors. Finally, three field blanks shall be deployed with the sampling detectors in the school setting. They shall then be returned to the laboratory for analysis. If more than 180 test kits are used, the standard 5% blank number can be resumed.
- The device placement log, mentioned below, should be used to document the devices used. Blanks should be included in the device log.

Device placement and floor plan should be included for each school building to be tested. All devices used, including duplicates and blanks, should be included in the device log. Please see the Sample Quality Assurance plan attached to this document for examples of device logs and building floor plans.

Spiked Measurements

Spikes are completed by exposing known radon concentrations to measurement devices. This allows the accuracy of the measurement devices to be determined as well as the accuracy of the laboratory analysis.

- The number of spikes should be 3% of all measurements taken within the school. Spikes need to take place within the same batch of test kits that will be used for testing. After spiking occurs, spiked devices need to be returned to the laboratory for analysis during the same period as the non-spiked devices.
- Once the laboratory has determined the concentration of the spiked measurement, the measurement is compared to the reference facility where the spike took place. The two measurements (measured value and target value) are compared using the Relative Percent Error (RPE) formula.
- Generally, the value of RPE should be between +10% and -10%, but a range of +20% to -20% is still considered “in control”. Furthermore, a range outside of +/- 20% but inside +/-30% is the warning level while any percentage outside of +/- 30% is the control limit.

Steps for Radon Testing

The purpose of initial screening measurements is to identify rooms that have a potential for elevated radon levels (e.g., levels of 4.0 pCi/L or greater) during the occupied school year.

1. A thorough documentation of occupied testing condition should be completed that details the unique sectors and typical HVAC operating procedures of the school building.

2. A Test Kit Placement Log and Test Kit Location Floor Plan should be prepared for each school in which radon measurements are conducted. The school’s emergency escape map typically provides the most accurate and up-to-date information.

    a. Test kit location should be accurately recorded on both the device log and floor plan. Test kit location should be recorded within three reference distances (x,y,z) consisting of 2 walls and floor of the room. See the Radon Test Kit Placement Strategy and Protocol Checklist, Sample Test Kit Placement Log, and Floor Plan included in Appendix A for additional assistance.

3. The appropriate number of test kits must be determined in advance and purchased from a source approved by IDPH. Testing must be done following the directions on the test kit.

4. Measurement devices should be placed in all frequently-occupied rooms in contact with the ground. There should be at least one test kit per floor with a test rate of 10% for rooms located on the second and third floor.

5. Testing should occur during periods where students and teachers are normally present (during weekdays).

6. In addition to placing test kits to determine radon concentrations, additional test kits should be provided to serve as quality control measures (duplicate and blank measurements).

    a. *Blank measurements:* represent 5 percent of the number of test kits deployed, or a maximum of 25 test kits, whichever is less within the building.

    b. *Duplicate measurements:* represent 10 percent of the number of test kits deployed, or a maximum of 50 test kits, whichever is less within the building.

7. Test kit placement must be:
    a. Where they are least likely to be disturbed or covered up.
    b. At least 3 feet from doors, windows to outside or ventilation ducts.
    c. At least 1 foot from exterior walls.
    d. At least 20 inches to 6 feet from floor
    e. Approximately every 2,000 square feet for large spaces.

8. Test kits must *NOT* be placed:

    a. Near drafts resulting from heating, ventilating vents, air conditioning vents, fans, doors, and windows.
    b. In direct sunlight
    c. In areas of high humidity such as bathrooms, kitchens, laundry rooms, etc.
    d. Where they may be disturbed at any time during the test.

9. Test kits may be suspended in the breathing zone, and if suspended, shall be 20 inches to 6 feet above the floor, at least 1 foot below the ceiling. In a Pod floor plan, test kits are often suspended.

10. Test kits must be used under closed conditions (closed windows/doors except for normal exit/entry).

    a. *Closed conditions:* Short-term tests should be conducted under closed conditions to obtain representative and reproducible results. Open windows and doors permit the movement of outdoor air into a room and subsequently dilute radon gas, producing a lower/reduced measurement result. Closed building conditions should be maintained for at least 12 hours prior to the start of 2 to 5 day measurements (e.g., initiate testing after a weekend).

    b. All external doors should be closed except for normal use – structural defects need to be repaired prior to testing.

    c. Closed conditions must be verified when placing and retrieving test kits. Closed conditions should be documented in the measurement files.

11. Test kits are generally placed during colder months (October through March, depending on geographical location).

    a. *Colder months:* Since testing under closed conditions is important to obtaining meaningful results from short-term tests, schools should schedule their testing during the coldest months of the year. During these months, windows and exterior doors are more likely to be closed and the heating system is more likely to be operating. This usually results in the reduced intake of outside air. Moreover, studies of seasonal variations of radon measurements in schools found that short-term measurements may be more likely reflect the average radon level in a room for the school year when conducted during the winter heating season.

    b. Check and document local weather forecasts prior to placing test kits. Do not conduct measurements of less than 96 hours during severe storms or period of high winds. The definition of severe storm by the National Weather Service is one that generates winds of 58 mph and/or ¾ inch diameter hail and may produce tornadoes.

12. Test Kits should be placed during weekdays with HVAC systems operating normally.

    a. *Weekday testing:* When using 2 to 5 day short-term tests, it is recommended that testing is conducted on weekdays with HVAC systems operating normally. This approach measures radon levels under the typical weekday conditions for that school and eliminates the burden of weekend testing and non-routine adjustments to the HVAC systems. Based on USEPA studies, the recommendation to conduct 2 to 5 day tests on weekdays does not invalidate radon measurements conducted on weekends with HVAC system operating continuously.

    b. Any air conditioning systems that recycle interior air may be operated.

    c. Window air conditioning units may be operated in a re-circulating mode and must be greater than 20 feet from the test kit.

    d. Ceiling fans, portable humidifiers, dehumidifiers and air filters must be greater than 20 feet from the test kit.

    e. Portable window fans should be removed or sealed in place.

    f. Fireplaces or combustion appliances (except for water heaters/cooking appliances) may not be used unless they are the primary source of heat for the building.

13. If radon mitigation systems are operating in the school, they should be functioning.

14. Schools should *avoid* conducting initial measurements under the following conditions:

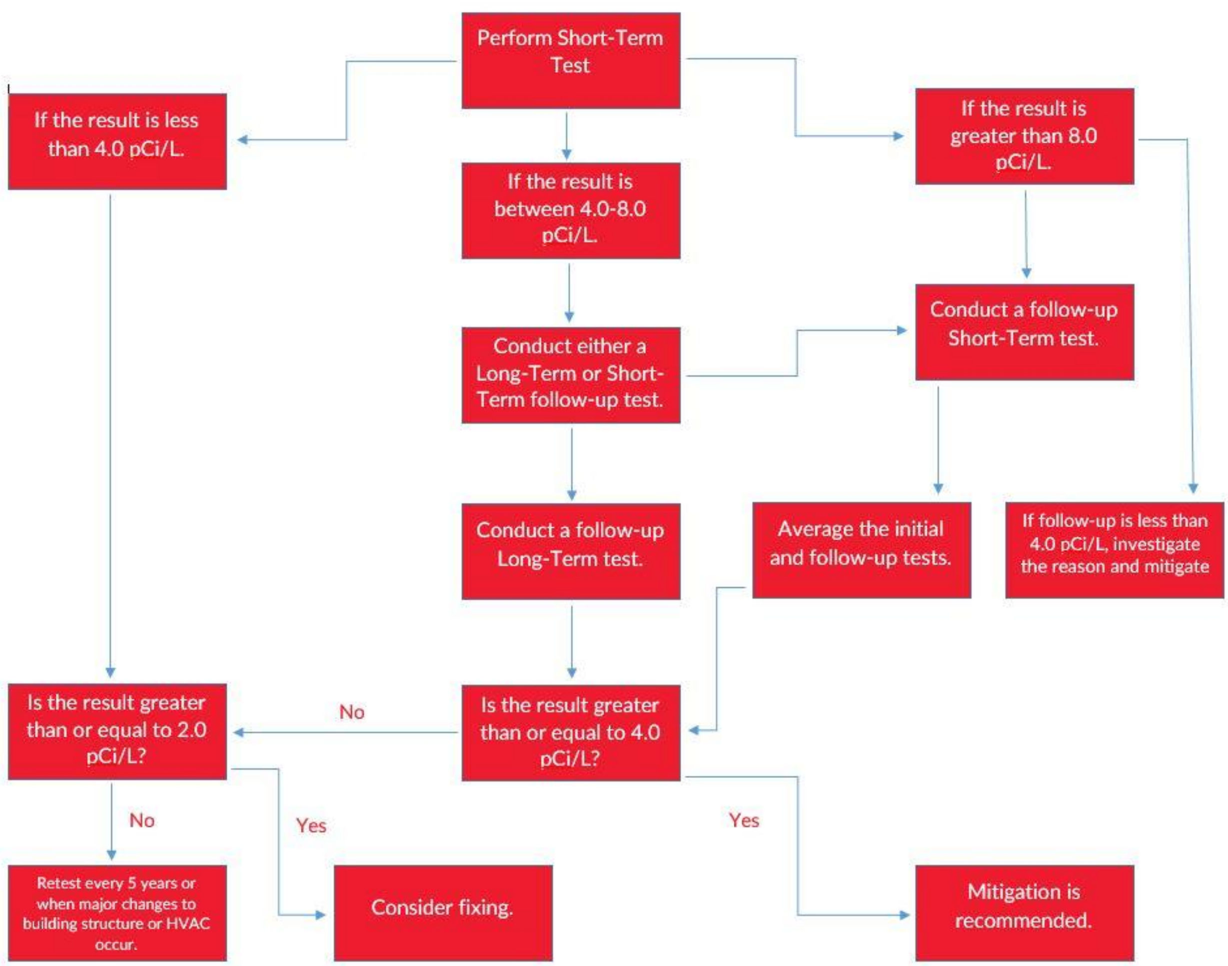
    a. During abnormal weather or barometric conditions (e.g., storms and high winds)

Weather conditions: If major weather or barometric changes are expected, it is recommended to postpone the 2 to 5 day test. USEPA studies show that barometric changes affect indoor radon concentrations. For example, radon concentrations can increase with a sudden drop in barometric pressure associated with storms.

b. During structural changes to a school building and/or the renovation or replacement of the HVAC system

How to Determine If Mitigation Is Needed

The decision to mitigate depends on the measured radon levels and the type of test(s) conducted. Below is a flowchart to help determine recommended mitigation action.



If mitigation is necessary, schools can reduce radon levels by working with a licensed radon mitigation professional. The professional will proceed by performing diagnostic testing and ultimately making decisions for mitigation. Diagnostics involve the evaluation of radon entry points and the identification of the appropriate radon reduction techniques.

Types of Mitigation Systems

Schools and large commercial buildings are more complex than residential homes. Like most other indoor air contaminants, radon can best be controlled by reducing entry into the building, rather than removing it once it has entered. Radon can be controlled through:

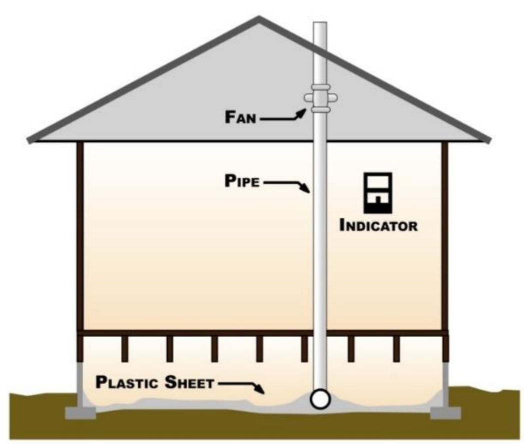
- Soil Depressurization – A suction fan is used to produce a low-pressure field under the building slab. This low-pressure field prevents radon entry by causing air to flow from the building into the soil (rather than from the soil into the building).
- Building Pressurization – Indoor/subslab pressure relationships are controlled to prevent radon entry. More outdoor air is supplied than exhausted so the building is slightly pressurized compared to both the exterior of the building and the subslab area.
- Sealing Entry Routes – Seal major entry routes to prevent or minimize radon entry.

New School Buildings

For new school buildings, the above radon prevention techniques are relatively inexpensive and easy to install during construction.

Existing School Buildings

- The most effective and frequently used radon reduction technique for soil depressurization is active soil depressurization (ASD). ASD creates a lower pressure beneath the slab to reverse the flow of air through a building foundation, thereby reducing radon entry. A series of pipes penetrate the slab or foundation walls. A high suction fan is attached to these pipes to vent the soil gas from beneath the building foundation.



- The use of the HVAC system may be more appropriate because of local building code requirements, occupancy patterns, school building construction or operation and levels of radon. This method directly influences radon entry by altering air pressure differences between the radon in the soil and building interior. Depending on the type and operation, a HVAC system can create positive or negative air pressure. Positive pressure can prevent radon entry, while negative pressure enhances radon entry. The positive pressure can be achieved through additional heating, cooling and/or dehumidification, along with enhanced routine operation and maintenance.
- Radon enters the building from the soil through cracks and openings in the slab and sub-structure, however, it is difficult, if not impossible, to seal every crack and penetration. Therefore, sealing radon entry routes is often used in conjunction with the other mitigation techniques.

Summary Report

The following items need to be documented in the final Summary Report:

- Test site location
- Contact information for measurement company
- Name and identification of measurement professional
- Contact information for laboratory
- Assessment of test conditions
- Summary of test results and recommended actions
- Status of mitigation system (if applicable)
- Test limitations

What Other Information Is Needed?

- All individual measurement results
- Copy of written report of results
- Exact start and stop dates and times of measurement period for each detector
- Diagram of test area noting exact location of all detectors placed
- Placement plan retrieval records

- Protocol deviations
- Noninterference measures
- Report of temporary building conditions
- A record of all quality control measures associated with the test

Frequently Asked Questions About Radon and Schools

1. Does radon cause headaches, eye irritation, or sick-building syndrome? *No.*
2. Do children have a greater risk of cancer from radon exposure?

   Children usually are more sensitive to environmental pollutants; however, there is no conclusive data that suggests children are more at risk than adults from radon exposure.
3. Is there a hazard from touching/being near the radon test kit? *No.*
4. Do building materials emit radon?

   The primary route of radon entry to a building is through the soil. However, there may be a few building materials that will emit small amounts of radon gas, such as granite, concrete, gypsum board (sheet rock), bricks, and field stone. This is RARELY the source because most of these materials are very dense. This means that if there is radon-producing radium in these materials, only a small amount of the radon gas near the surface ever makes it out into the environment.
5. Should testing be delayed if the school is planning major renovations to the building or the HVAC system?

   Initial and follow up tests should be conducted prior to major HVAC or building renovation. Testing can show if a radon mitigation system needs to be installed as a part of renovation. Testing must also be done after a renovation is completed.
6. Should upper floors of a school or building be tested?

   Upper floors may indeed have elevated levels of radon. It is recommended that you test at least one room per floor. Ten percent of rooms located on the second and third floor should be tested.
7. In schools with a basement level (below ground level), the first floor is often built at ground level, and therefore is in contact with the soil, only along it's outside edge. Should this floor be tested?

   Although this floor appears to have limited contact with the soil, the outside rooms may have openings permitting radon entry and should be tested if they are frequently occupied. If the basement rooms are occupied, or expect to be occupied in the future, the basement *rooms should also be tested. In addition, schools with crawl spaces between the ground and first floor should test all frequently occupied first floor rooms.*

8. Nearby homes and schools have reported no elevated levels of radon. Should a school still test?

   Yes, radon levels vary with geology, man-made and building structure, HVAC systems, etc. The only way to know if radon is present is to test; and re-test every five years (or whenever there is significant renovation).

9. What are the costs of testing in schools for radon?

   The cost may be dependent on the number of rooms to be tested and the type of test kit used.

10. If a room's short term initial test result is very high (for example above 10.0 pCi/L) should a follow-up measurement be conducted?

    Follow up measurements are usually recommended before making any further decisions.

11. Should a room be retested if there evidence of tampering? *Yes.*

12. When two devices (duplicates) are placed in a room during initial testing, which measurement result is taken as the test result?

    Both tests are recorded, but the average is taken as the test result.

13. What should be done if a device is picked up late or handled incorrectly?

    All test kits should be handled in accordance with manufacturer's instructions. If there is any discrepancy or problems, the serial number of the device should be recorded and noted to the laboratory doing the analysis.

Please direct additional questions to:

- Rick Welke – (515) 281-4928
  Iowa Radon Program

- Melinda (Mindy) Uhle – (515) 242-6131
  Iowa Radon Program
  Melinda.Uhle@idph.iowa.gov

- Iowa Radon Hotline – (800) 383-5992

References

AARST Consortium on National Radon Standards. 2014. “Protocol for Conducting Measurements of Radon and Radon Decay Products in Schools and Large Buildings”.

Iowa Department of Public Health. “Radon Resources”. http://idph.iowa.gov/radon/resources

Klepis, Neil E., Nelson, William C., Ott, Wayne R., Robinson, John P., Tsang, Andy M., Switzer, Paul. 2001. “The National Human Activity Pattern Survey (NHAPS): A Resource for Assessing Exposure to Environmental Pollutants”.

National Cancer Institute. “Radon”. http://www.cancer.gov/about-cancer/causes-prevention/risk/substances/radon.

USEPA Air and Radiation. “Radon Measurement in Schools: Self-Paced Training Workbook”.

USEPA Air and Radiation. “Reducing Radon in Schools: A Team Approach”

USEPA Air and Radiation. 1993. “Radon Measurement in Schools Revised Edition”

USEPA Air and Radiation. 1994. “Radon Prevention in the Design and Construction of Schools and other Large Buildings”

Additional Resources

Note: The following Tables are from the 2014 Protocol for Conducting Measurements of Radon and Radon Decay Products in Schools and Large Buildings by AARST Consortium on National Radon Standards.

Table 1: Operational Design of HVAC (AARST 2014)

Group 1: Basic Heating and Cooling

A dedicated system for each room or unique area that does not supply additional fresh air for ventilation.

- Forced-air heating and air conditioning (HAC) systems (such as normally seen in single-family residences).
- Ductless Split System: One system for cooling and one system for heat (i.e. Window AC for cooling and baseboard heating)
- Ductless Systems:
    - Non-Forced-Air Hot and Cold Water Circulation (radiator systems)
    - Window AC (with fresh air closed)
    - Wall or baseboard heating/cooling

Group 2: Multi-zone Systems

Independent systems and controls for different areas within the same room or unique sector.

Group 3-a: Variable Air Distribution

Systems where the airflow from a single air handler is distributed to multiple rooms or locations with independent controls for duct dampering within each room. Such systems include Variable Air Volume (VAV) systems or systems with fixed volume return vents and controls for dampering supply air.

Group 3-b: Variable Outdoor Air Ventilation

Systems that add outdoor ventilation:

- For individual rooms (i.e., Unit Ventilators)
- For multiple rooms (i.e., each system serves an area)
- For a whole building

Table 2: Evaluation of testing conditions compared to "Normal Occupied Operating Conditions" (AARST 2014)	
Building Operating Conditions to Report:	**Report**
1.a Operating conditions that represent the greatest amount of significantly occupied time.	A Technical description
1.b If the building operating condition represents the greatest amount of significantly occupied time?	"Yes" or "No" description
2.a Operating conditions that emphasize when clear characterization of radon hazard is most likely.	A Technical description
2.b If operating conditions emphasize when clear characterization of radon hazard is most likely?	"Yes" or "No" description
3. Any additional considerations.	As needed
4. Descriptions of conditions and possible effects that might warrant repeating the test and recommended timetable for repeating the test.	Conditions and Recommended Retest Timing

Quality Assurance Project Plan

Sample School District #123

Radon Measurements of:
Sample Elementary School
123 Sample Street
Sample, IA 60000

Performer: ______________________________ Date: ____________

DEFINITIONS

Radon – A colorless, odorless, tasteless, radioactive gas that is produced from the decay of naturally occurring uranium in the soil.

Duplicates - Duplicate measurements provide a check on the precision of the measurement result and allow the user to make an estimate of the relative precision. Large precision errors may be caused by detector manufacture or improper data transcription or handling by suppliers, laboratories, or technicians performing placements. Precision error can be an important component of the overall error. The precision of duplicate measurements are monitored and recorded as quality records.

Background Field Measurements (Blanks) - Measurements made by analyzing unexposed (closed) detectors that accompanied exposed detectors to the field. The School District use of blanks is to assess any change in analysis result caused by exposure other than in the environment to be measured. Results of blanks may be subtracted from the actual field measurements before calculating the reported concentration. Background levels may be due to leakage of radon into the detector, detector response to gamma radiation, or other causes.

Closed-Building Conditions - Means keeping all windows closed, keeping doors closed except for normal entry and exit, and not operating fans or other machines which bring in air from outside. Fans that are part of a radon-reduction system or small exhaust fans operating for only short periods of time may run during the test.

1.0 PROJECT DESCRIPTION

1.1 Site Location History/Background Information

Site Description:

Sample School was built in 1950 with additions in 1970, 1990, and 2010. The total square footage is approximately 80,000 square feet.

Sample School uses central heating and air and a full HVAC system.

Sample School houses grades K through 5 with approximately 500 students annually.

1.2 Radon Measurement Activities

The following employee(s) will perform screening measurements for radon in the facilities of the Sample School District #123.

1. Mr. Sample Sampleton
2. NAME

The Sample School District #123 will perform the following activities:

Radon Measurements

- Employees will perform measurements with sample devices.
- Measurements will be placed at the Employees discretion using their knowledge obtained from this guide or previous knowledge.

Quality Assurance Measurements

- One field duplicate for every 10 radon measurements.
- One field blank for every 20 radon measurements.
- Three spikes for every 100 radon measurements.

Follow-up Measurements

- Additional follow-up measurements will be performed only where initial results of 4.0 picocuries per liter of air (pCi/L) or more are detected or an issue arises with quality assurance measures (duplicates, blanks, and spikes).

Radon Test Placement Strategy and Protocol Checklist

NOTE: This document has been prepared to aid school districts performing radon testing in schools. The step-wise approach is aimed to help school districts determine where to test, how many test kits are required, where to place test kits, and proper documentation of the process. This document is meant to be used as a general guideline, not a mandate, as each school will present different situations. If specific questions or issues arise regarding testing in your school contact the Iowa Radon Hotline at 1.800.383.5992.

Determine placement strategy and number of test kits needed.

___ 1) Get a current copy of the schools floor plan - ALL levels (emergency exit maps work well for this purpose)

___ a) Make sure all rooms in the building floor plan are individually labeled, if they are not then create labels for them

___ b) Determine different foundation types found throughout the building and indicate which sections of the building are over each foundation on the floor plan.

___ 2) Determine the structurally lowest rooms in the building for all foundation types that students and faculty could spend time in (even if the room is not currently being utilized). DO NOT include areas such as storage, bathrooms, stairways, hallways, and elevator shafts.

___ Determine upper floor classrooms that will be tested. (See section "What Rooms Should Be Tested" for more information on upper floors)

At the end of section 2) you should have a rough list of rooms that need to be tested.

___ 3) Determine if any of the rooms selected are larger than 2,000 square feet.

___ If YES, how many? _____ how big is the room(s)? ____________________ (1 radon test kit must be placed for every 2,000 sq. ft.)

4) Determine the number of test kits needed to test the building take:

   ______ (total number of rooms after section 2).

   ______ (number of rooms over 2,000 square feet after section 3).

   ______ (number of rooms over 4,000 square feet after section 3).

   ______ (number of rooms over 6,000 square feet after section 3).

5) ______ = Number of Test Kits Needed to Test the School.

Determine the Number of Quality Control Measurements Needed

6) Determine the number of duplicate measurements that need to be deployed during measurement. To do this take the number of test kits needed to test the school determined in Section 5 times 0.1 (10% of all test kits deployed).

   ______ Test Kits Needed x 0.1 (10%) = ______number of duplicate tests.

   (NOTE: Round up to the next whole number)

7) Determine the number of blank measurements that need to be deployed during measurement. To do this take the number of test kits needed to test the school determined in Section 5 times 0.05 (5% of all test kits deployed).

   ______ Test Kits Needed x 0.05 (5%) = ______ number of blank tests.

8) Determine the number of spiked measurements that need to be deployed during measurement. To do this, take the number of test kits needed to test the school determined in Section 5 times 0.03 (3%). Note: There needs to be a minimum of 100 test locations.

   ______ Test Kits Needed x 0.03 (3%) = ______ number of spiked tests.

   (NOTE: Round up to the next whole number)

Determine total number of test kits needed to perform all required tasks.

______ = Test Kits Needed to Test the School determined in Section 5.

______ = Number of duplicate tests determined in Section 6.

______ = Number of blank tests determined in Section 7.

______ = Number of spiked tests determined in Section 8.

______ = **Total Number of Test Kits to Be Placed In the School**

Test Kit Placement

Once the number of test kits is determined, they need to be placed in the frequently occupied rooms identified above.

9) Be sure to check these items before placing the radon test kits:

___ Closed conditions have been maintained in the building for 12 hours.

___ HVAC system is operating as it normally would when students and faculty are present.

___ Testing is being done during a time that students and faculty are present.

10) As detectors are placed in the rooms determined during section 1, thorough and accurate data needs to be recorded on the device log and floor plan (see sample below). Protocol for all test kits include the following; be sure that each detector placed is:

___ in a location where it will be undisturbed.

___ 3 feet from all doors and windows

___ at least 1 foot from all exterior walls

___ out of direct air flow from vents

___ out of direct sunlight

___ 4 inches from all other objects

___ 20 inches - 6 feet from the floor

___ 4 feet from heat source

11) Specific protocol for duplicate measurements. If the test kit you are placing is a duplicate measurement also be sure to place the test kit:

___ Placed duplicate (side-by-side) test kit 4-5 inches away from test kit for that room.

12) Specific protocol for blank measurements. If the test kit you are placing is a blank measurement, also be sure to:

___ Keep the test kit in the original packaging

___ Place the test kit next to the room test kit 4-5 inches away.

13) Testing Period. The minimum length of time test kits should be left out is 48 hours. It's recommended that kits be placed at the start of a school day and retrieved at the end of third school day. See manufacturer's instructions for more specific recommendations. In general:

Short term tests last 2-90 days
Long term tests last 91-365 days

14) Retrieving Test Kits. Once the testing period has elapsed, test kits need to be retrieved. Complete the data sheet when retrieving detectors.

___ Record ending date and time information on the device log

15) Protocol for measurement and duplicate test kits.

___ Record ending date and time information on the device log.

___ Record ending information on the test kit package (if required).

___ Seal and prepare test kits to be mailed to the lab by the manufacturer's instructions.

16) Protocol for blank test kits.

___ Record ending information on the device log.

17) Mail all test kits (measurement, duplicate, blank, and spike) immediately after retrieving from testing location.

SAMPLE Detector Log for Measuring Radon in Schools

This type of document should be used ALONG WITH floor plan (attached) for proper documentation of radon detector location.

Example placements:
1) for regular classroom (CR7)
2) duplicate measurement (CR32)
3) blank measurement (CR35)
4) room over 2,000 sq. ft. (Gym A) are provided

Name of Building being Tested: South Elementary – ## Street, City, Zip Code

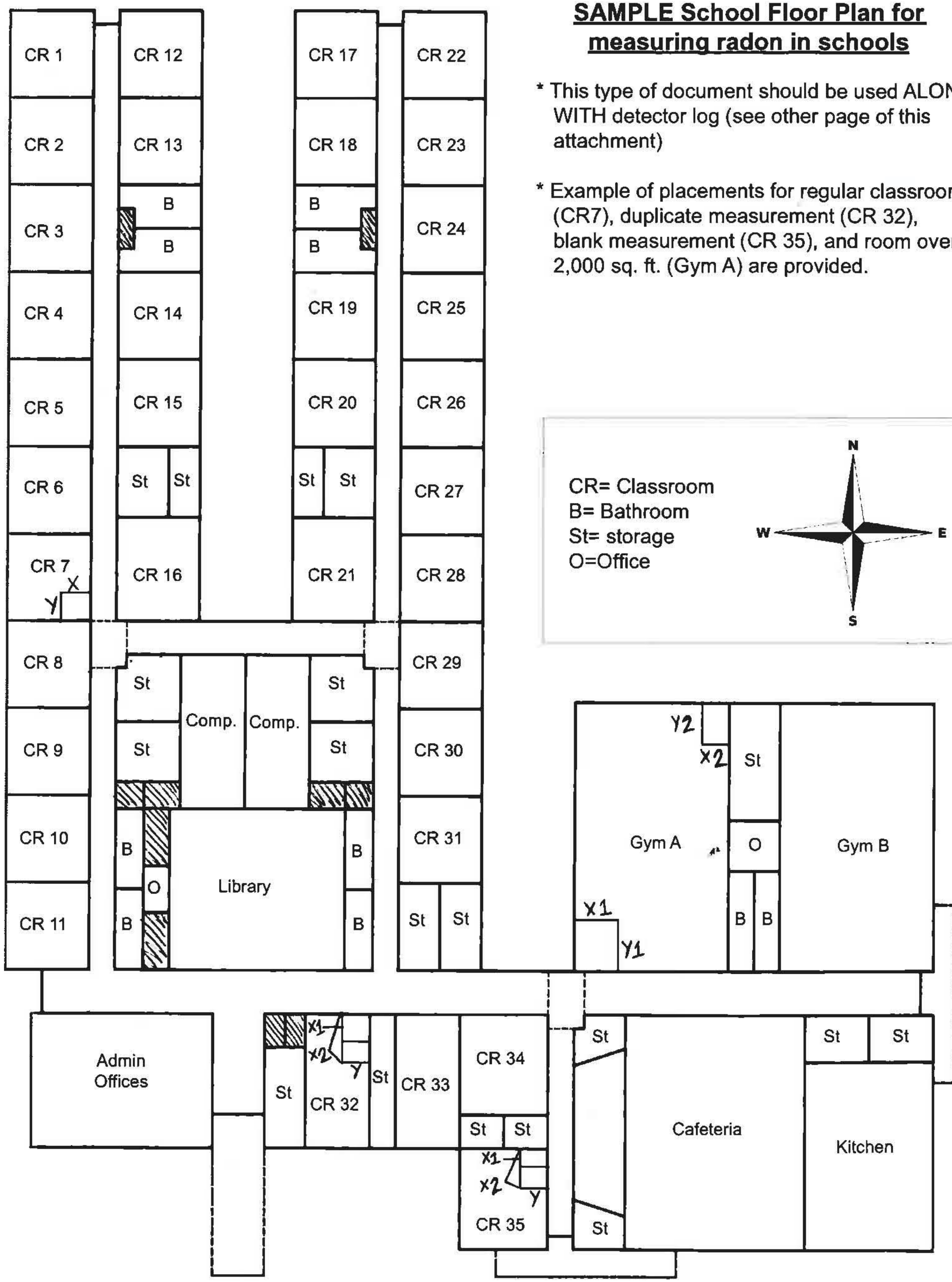
Name of Individuals performing testing: John Doe

Detector Number	Location	Duplicate/ Blank	Distance of X	Distance of Y	Distance of Z (floor)	Date Started	Time Started	Date Ended	Time Ended
001	CR 7		3’ 1”	4’ 3”	3’ 6”	1/1/2010	6:00am		
002	CR 32	Duplicate	3’ 4”	5’ 1”	3’ 5”	1/1/2010	6:05am		
003	CR 32	Duplicate	3’ 8”	5’ 1”	3’ 5”	1/1/2010	6:07am		
004	CR 35		4’ 2”	8’ 3”	4’ 1”	1/1/2010	6:12am		
005	CR 35	Blank	4’ 6”	8’ 3”	4’ 1”	1/1/2010	6:14am		
006	Gym A (1)		5’ 3”	6’ 2”	5’ 6”	1/1/2010	6:19am		
007	Gym A (2)		7’ 8”	4’ 6”	5’ 6”	1/1/2010	6:22am		

SAMPLE School Floor Plan for measuring radon in schools

* This type of document should be used ALONG WITH detector log (see other page of this attachment)

* Example of placements for regular classroom (CR7), duplicate measurement (CR 32), blank measurement (CR 35), and room over 2,000 sq. ft. (Gym A) are provided.



CR= Classroom
B= Bathroom
St= storage
O=Office

DO NOT TOUCH! RADON TEST IN PROGRESS!

This is a screening test for the Sample School District #123 and the radon detector should not be moved. Windows should remain closed and the radon detector will be picked up on ___________________.

Sample detector is placed here.

The Sample School District #123 is testing for radon because radon is a colorless, odorless, naturally occurring radioactive gas that comes from uranium in the soil and can cause lung cancer. The Surgeon General warned about the health risk from exposure to radon in indoor air. Because radon is the leading cause of lung cancer for non-smokers in the US and breathing it over prolonged periods can present a significant health risk, the Surgeon General urged Americans to test their homes. The United States Environmental Protection Agency (USEPA) estimates that around 21,000 lung cancer related deaths occur annually in the US with 400 of those in Iowa

Because of the danger of radon, it's recommended that every occupied school building of a school district be tested every 5 years for radon. For questions about this test, contact ___________________________.

Floor Plan Here

Detector Log for Measuring Radon at
Sample School, 123 Sample Street, Sample, IA 60000

Name of Individuals performing testing: ____

Detector Number	Location of Detector	Duplicate/ Blank	Distance of X	Distance of Y	Distance of Z (floor)	Date Started	Time Started	Date Ended	Time Ended